CLAIMS

WHAT IS CLAIMED IS:

1. A method of digitally modulating a laser beam responsive to digital data that includes a grayscale level, comprising:

generating a pulsed laser beam that includes a series of periodic light pulses each having an approximately equal energy content; and

modulating said pulsed laser beam in an element of a spatial light modulator to gate a number of pulses corresponding to the grayscale level of said digital data, including transitioning said element substantially in an interpulse period between laser pulses.

2. The method of claim 1 further comprising projecting said modulated beam from said laser element onto a screen.

3. The method of claim 1 wherein said digital data comprises color information including grayscale levels of a first color, a second color, and a third color, wherein said first laser pulses have the first color, further comprising:

generating a second pulsed laser beam that includes a series of periodic light pulses having the second color, each pulse providing an approximately equal energy content;

modulating said second pulsed laser beam in an element of a second spatial light modulator to gate a number of pulses corresponding to the grayscale level of said digital data for the second color, including transitioning

said element substantially in an interpulse period between laser pulses.

generating a third pulsed laser beam that includes a series of periodic light pulses having the third color, each pulse providing an approximately equal energy content; and

modulating said third pulsed laser beam in an element of a third spatial light modulator to gate a number of pulses corresponding to the grayscale level of said digital data for the third color, including transitioning said element substantially in an interpulse period between laser pulses.

4. The method of claim 3 wherein said first pulsed laser beam is red, said second pulsed laser beam is green, and said pulsed third laser beam is blue, and further comprising combining the red, green, and blue modulated beams to provide a full color modulated beam.

5. A method of digitally modulating a laser beam responsive to digital data that includes grayscale levels for each pixel in a frame, comprising:

generating a pulsed laser beam that includes a series of periodic light pulses each having an approximately equal energy content; and

modulating said pulsed laser beam in a plurality of elements of a spatial light modulator to gate a number of pulses from each element corresponding to the grayscale level of said digital data for each pixel for each frame, including transitioning said elements substantially in an interpulse period between laser pulses, thereby providing a modulated beam.

6. The method of claim 5 further comprising projecting said modulated beam onto a screen.

7. The method of claim 5 wherein said digital data comprises color information including grayscale levels of a first color, a second color, and a third color for each pixel for each frame, wherein said first laser pulses have the first color, further comprising:

generating a second pulsed laser beam that includes a series of periodic light pulses having the second color, each pulse providing an approximately equal energy content;

modulating said pulsed laser beam in a plurality of elements of a second spatial light modulator to gate a number of pulses from each element corresponding to the grayscale level of said digital data for the second color for each pixel for each frame, including transitioning said elements substantially in an interpulse period between laser pulses, thereby providing a second modulated beam.

generating a third pulsed laser beam that includes a series of periodic light pulses having the third color, each pulse providing an approximately equal energy content; and

modulating said pulsed laser beam in a plurality of elements of a third spatial light modulator to gate a number of pulses from each element corresponding to the grayscale level of said digital data for the third color for each pixel for each frame, including transitioning said elements substantially in

an interpulse period between laser pulses, thereby providing a third modulated beam.

8. The method of claim 7 wherein said first pulsed laser beam is red, said second pulsed laser beam is green, and said third pulsed laser beam is blue, and further comprising combining the red, green, and blue modulated beams to provide a full color modulated beam.

9. A digital illumination system comprising:

a pulsed laser source that provides a laser beam including a series of periodic pulses and an interpulse period between pulses, each pulse having substantially equal energy content.

a spatial light modulator that receives said laser pulses from said pulsed laser source, said modulator including a plurality of elements each of which is configured in one of a first state, a second state, and a transition between said first state and said second state, said transition having an associated transition interval;

a modulation driver synchronized with said laser driver, said modulator driver controlling transitions between said first and second state of said elements, said transitions having a non-zero phase with reference to said laser pulses so that said transition intervals occur in interpulse periods; and

an optical system for propagating the modulated laser beam from the light modulator.

10. The digital illumination system of claim 9 wherein said pulsed laser source comprises a Q-switched laser.

11. The digital illumination system of claim 9 wherein said pulsed laser source comprises a mode-locked laser, and further comprising an optical switch arranged to switch the pulsed laser output of said mode-locked laser and provide said series of periodic pulses and said interpulse period between pulses.

12. The digital illumination system of claim 9 wherein said spatial light modulator comprises a DMD array.

13. The digital illumination system of claim 9 further comprising:

a second pulsed laser source and a second spatial light modulator arranged to modulate the laser beam from said second pulsed laser to provide a second modulated beam;

a third pulsed laser source and a third spatial light modulator arranged to modulate the laser beam from said third pulsed laser to provide a third modulated beam; and

a beam combiner that combines the first, second, and third modulated beams.

14. The digital illumination system of claim 13 wherein said first pulsed laser source provides red light, said second pulsed laser source provides green light, and said third pulsed source provides blue light.

15. The digital illumination system of claim 9 wherein said pulsed laser source provides a plurality of synchronized pulsed laser beams including a first, second, and third laser beam, said laser beams being synchronized with each other to provide a series of pulses having the substantially same frequency and phase, said spatial light modulator arranged to modulate said first laser beam to provide the first modulated beam and further comprising a second spatial light modulator arranged to modulate said second laser beam to provide a second modulated beam; and a third spatial light modulator arranged to modulate the third laser beam, wherein said first, second, and third light modulators are synchronized with said plurality of pulsed laser beams.

16. The digital illumination system of claim 9 further comprising a projection system including a screen and projection optics arranged to receive the modulated beam from the light modulator and project it onto the screen.

17. A digital projection system for projecting an image, comprising:

a pulsed laser source that controls the laser to provide a pulsed laser beam including a series of periodic light pulses each having an approximately equal energy content, and an interpulse period between pulses during which substantially no light energy is emitted;

an image processor coupled to receive image data;

a modulator driver coupled to said image processor, said modulator driver being frequency-synchronized with said pulsed laser source with a non-zero phase delay with respect to said pulsed laser source;

a spatial light modulator array coupled to said modulator driver, said

array including a plurality of elements arranged to be illuminated by laser pulses from said pulsed laser source, each element configured in one of a first state, a second state that gates an illuminating pulse to provide a gated pulse, and a transition that has an associated transition interval between said first state and said second state, wherein said phase delay is selected so that transition intervals of modulator elements occur substantially in the interpulse period between light pulses, said modulator array outputting a modulated beam that comprises a plurality of gated pulses; and

a projection system that projects said modulated beam to provide an image.

18. The digital projection system of claim 17 wherein said pulsed laser source comprises a Q-switched laser.

19. The digital projection system of claim 17 wherein said pulsed laser source comprises a mode-locked laser, and further comprising an optical switch arranged to switch the pulsed laser output of said mode-locked laser and provide said series of periodic pulses and said interpulse period between pulses.

20. The digital projection system of claim 17 wherein said spatial light modulator comprises a DMD array.

21. The digital projection system of claim 17 wherein said first pulsed laser source provides red light, and further comprising:

a second pulsed laser source that provides green light and a second spatial light modulator arranged to modulate the laser beam from said second pulsed laser to provide a green modulated beam;

a third pulsed laser source that provides blue light and a third spatial light modulator arranged to modulate the laser beam from said third pulsed laser to provide a blue modulated beam; and

a beam combiner that combines the red, green, and blue modulated beams to provide a single modulated beam supplied to said projection system.

22. The digital illumination system of claim 17 wherein said pulsed laser source provides a plurality of synchronized pulsed laser beams including a first, second, and third laser beam, each providing a different color, said laser beams being synchronized with each other to provide a series of pulses having the substantially same frequency and phase, said spatial light modulator arranged to modulate said first laser beam to provide the first modulated beam and further comprising a second spatial light modulator arranged to modulate said second laser beam to provide a second modulated beam; and a third spatial light modulator arranged to modulate the third laser beam, wherein said first, second, and third light modulators are synchronized with said plurality of pulsed laser beams.

23. A digital projection system, comprising:

laser means for generating a pulsed laser beam including a series of periodic light pulses each having an approximately equal energy content and an interpulse period between pulses during which substantially no light energy

is emitted;

means for modulating said pulsed laser beam to provide a modulated laser beam responsive to image data, including a spatial light modulator that has a plurality of elements arranged to be illuminated by said pulsed laser beam;

means for synchronizing a transition of said elements with said laser pulses so that transition intervals of said modulator elements occur substantially in the interpulse period between light pulses; and

means for projecting said modulated beam.

24. The digital projection system of claim 23 wherein said modulating means comprises an image processor coupled to receive image data and a modulator driver coupled to said image processor, said modulator driver frequency-synchronized with said pulsed laser source with a non-zero phase delay with respect to said pulsed laser source.

25. The digital projection system of claim 23 wherein said projecting means includes projection optics for projecting said modulated beam on a screen to provide an image.

26. The digital projection system of claim 23 wherein said spatial light modulator comprises a DMD array.

27. The digital projection system of claim 23 wherein:

said laser means further includes means for generating a second pulsed laser beam and a third pulsed laser beam;

said modulating means further includes a second and a third spatial light modulator arranged respectively to modulate said second and third pulsed laser beams to provide second and third modulated beams;

said synchronizing means further includes means for synchronizing a transition of the elements of said second and third modulators respectively with the laser pulses in said second and third laser beams so that transition intervals of said modulator elements occur substantially in the interpulse period between light pulses; and

said projecting means includes means for projecting said second and third modulated beams.

28. The digital projection system of claim 27 wherein said first laser beam is red, said second laser beam is green, and said third laser beam is blue, and further comprising a beam combiner that combines the red, green, and blue modulated beams to provide a single modulated beam.